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Peat and Muck in Agriculture

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PEAT has been used and studied in many parts of the world. Peat lands cover extensive areas from the Tropics to the Poles, including parts of the United States. Malaya has about a million acres; northern Europe, from Ireland to Finland, has large deposits. There is some peat in every land that has extensive swamps. With the exception of a few large basins like the Florida Everglades, peat deposits are most common in humid and cool temperate and subtemperate regions.

Much information on the origin, properties, marketing, and utilization of peat is scattered through the literature.[1] Most of the bulletins and journals containing this information are no longer available for distribution and can be obtained only from libraries. This circular, therefore, is designed to give a review of the information previously available on peat that appears to be of interest to the American people, and to present some new facts to bring it up to date.

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[1] From about 1910 to 1940, the United States Department of Agriculture published the results of investigations on plants that form peat (*11, 12, 13, 15*),[2] distribution of deposits (*2, 10, 11, 20*), resources (*14, 15*), marketing (*8*), uses (*7, 21, 42*), and the composition and properties of peat and muck (*9, 20*). Important contributions to the knowledge of peat also have been made in journal articles (*1, 19, 26, 61*) and State bulletins (*17, 22, 39, 60, 62, 63, 64*).

[2] Italic numbers in parentheses refer to Literature Cited, p. 28.

PEAT AS A COMMERCIAL PRODUCT

Nature of Peat

The term "peat" commonly designates soil material consisting essentially of partly decomposed vegetable matter accumulated under water or at least in places waterlogged most of the time.

Peat for the market falls into two general groups based upon its use, but the groups are not capable of sharp distinction. One group includes peats sufficiently acid for use with acid-loving plants; the other, peats that are more nearly neutral or even alkaline in reaction.

Peat has a relatively high nitrogen content (between 1 and 3 percent on a dry basis), but the nitrogen is usually very slowly available to plants (*34*). The content of various other nutrient constituents, such as phosphoric oxide (P_2O_5) and potash (K_2O), is too low to be important when peat is added to mineral soil. The water-holding power of peat is high, but variable. There are wide differences in botanical character, stage of decomposition, and state of subdivision. Furthermore, the water-holding power of peat that retains its original moisture is very different from that of peat that has been dried. All these factors influence the uses to which peat is put.

The terms "peat" and "muck" are often used synonymously, although there is a distinction between them. Traditionally, two broad groups of organic soils have been recognized on the basis both of mineral content and of degree of decomposition of the vegetable matter. Those low in ash and only partly decayed are generally called peat; those high in mineral content and thoroughly decomposed are known as muck. The relationships between mineral content and state of decomposition in the bog may differ greatly, depending on whether the mineral matter was carried in from surrounding areas or is mostly the accumulated ash of thoroughly rotted vegetation.

When the mineral matter present was derived largely from plants in place, peats usually contain less than 35 percent mineral matter, and mucks between 35 and 75 percent, on a dry-weight basis. Sometimes, however, clay, silt, or even sand may be carried into the bog by wind or drainage water. An important source of inert mineral matter in many peats is volcanic ash, which may amount to as much as 50 percent of the dry weight. When the organic matter can be identified as to botanical origin it may be called peat, even though the mineral content exceeds 35 percent. On the other hand, organic soils or deposits whose botanical identity is lost may properly be called muck, even though the mineral matter present amounts to less than 35 percent.

The nature of organic soils is such that no great degree of precision is possible in distinguishing peats from mucks. Some consideration, however, should be given to widely accepted regional usage of the terms. In much of the area in the Northeastern and North Central States cultivated soils of high organic-matter content are known as muck lands, even though the organic-matter content is above 65 percent and fragments of plant remains are identifiable. The organic deposits of central Florida are often known as muck or "custard apple muck," even though organic remains may be identified and the mineral content is low.

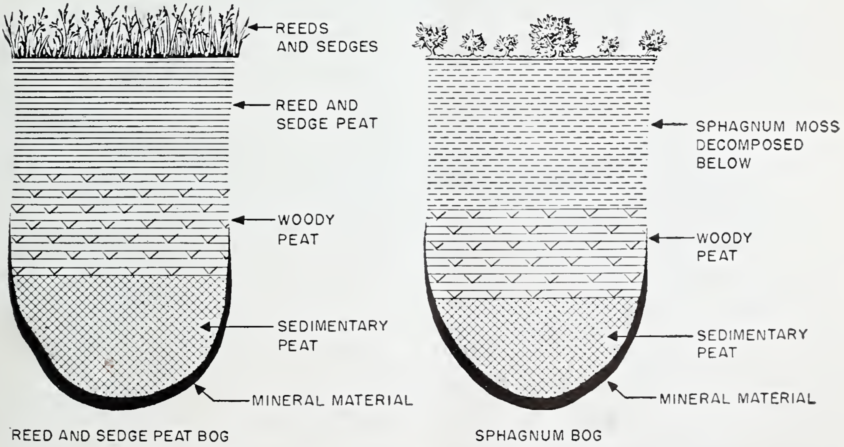
Commercial products taken from bogs are often designated as "peat humus" or by some similar term, indicating that the material is essentially humified. In general, such terms mean that the material has been decomposed to the extent of essential loss of its botanical identity. In most cases it is very dark, and conventional chemical tests show a high content of so-called humus (*54*).

How Peat Is Formed

Where evaporation is high peat is formed in low spots on poorly drained lands that are submerged most of the time, or in shallow ponds and marshes. In very humid and cool regions it may be formed also on steep slopes. Some peat deposits cover wide areas —for instance, the Everglades in Florida. Organic matter decomposes very slowly under water. Thus the remains of vegetation growing in water, or falling into it, tend to accumulate more rapidly than they decompose, until the accumulation of deposits is exposed to the air at the surface during dry periods. At this stage decomposition of organic matter keeps pace with its accumulation. As the level of the bog is raised, new types of vegetation appear in response to the changing environment.

A vertical cut through a peat deposit often reveals a series of layers that have originated from different kinds of plant materials (fig. 1). When the surrounding hills contain calcareous deposits, the product formed may be essentially neutral or even alkaline in reaction.

The materials making up a peat bog form irregular patterns, sometimes rather definite layers, varying in depth in different parts of the bog. The depth of the layers depends on the history of the bog, particularly on the length of time each phase of vegeta-



REED AND SEDGE PEAT BOG

SPHAGNUM BOG

FIGURE 1.—Typical profile of a peat formed primarily from reeds and sedges and of one formed chiefly from sphagnum moss.

tion lasted. In some sphagnum bogs studied, the surface layer of sphagnum-moss peat varied from 5 or 6 inches to 25 feet in thickness, often being 6 to 8 feet; the bed of reed-sedge peat below it varied from 2 to 12 feet; the stratum of woody peat below, or often above, the reed-sedge peat, varied from 4 inches to 1½ feet or was lacking; and the sedimentary peat at base of the deposit varied from none to a layer of 3½ feet.

TYPES OF PEAT

The vegetation from which peat is formed varies widely (fig. 2), as does also the character of each peat developed from it (*16*).

The physical and chemical properties of peat depend on the kinds of plants from which it was formed, on their degree of decomposition, and on the kind and quantity of mineral matter present. There is not yet general agreement on the classification of peats according to their botanical characteristics. For present purposes, peats may be divided according to gross botanical composition into the four following groups:

Sphagnum group.—Peat of this type is formed mainly of several species of sphagnum, usually intermixed with small quantities of various herbaceous plants and undershrubs, such as ferns and sedges, orchids, sundews, pitcherplants, and often cranberry. Also, these deposits occasionally contain lenses of wood or remains of shrubs, commonly of the heath family. This type of vegetation is similar to that of the European highmoor. Sphagnum-moss peat is usually loose, spongy, and often layered; it varies from light grayish brown to deep brown in color. It nearly always has a strongly acid reaction (*33, 41, 44, 45, 49*).

Hypnum and other mosses group.—These peats are made up mostly of disintegrated plants of hypnum, often associated with other mosses and with intermingled rootlets of sedges and other flowering plants. They are formed chiefly in areas with a slightly acid, neutral, or alkaline reaction. The material is brownish or drab, light, spongy, and matted, and often laminated and porous.

Reed-sedge group.—Deposits of the reed-sedge type are formed mainly in shallow areas around the border of water-filled depressions, of which they gradually take possession, or in boggy meadows. Important constituents of peats of this group are various plants of the sedge family (*Carex*, *Scirpus*, *Eleocharis*, *Rynchospora*, *Eriophorum*, and others), cattail (*Typha*), various grasses (particularly the reed *Phragmites;* also *Glyceria* and *Calamagrostis*), burreed (*Sparganium*), arrowhead (*Sagittaria*), and a miscellaneous assortment of shore and swamp-loving plants of other families. In their normal development, peats of this type are rather fibrous and somewhat felted or matted; they consist mainly, so far as recognizable vegetable matter goes, of roots and rootlets of the plants mentioned, but they often also contain the rootstocks or stems of the plants. They are light yellowish to reddish, rusty brown, or even blackish in color.

Shrub-and-tree group.—An important plant group represented is the heaths, which are mainly plants of acid habitats. They in-

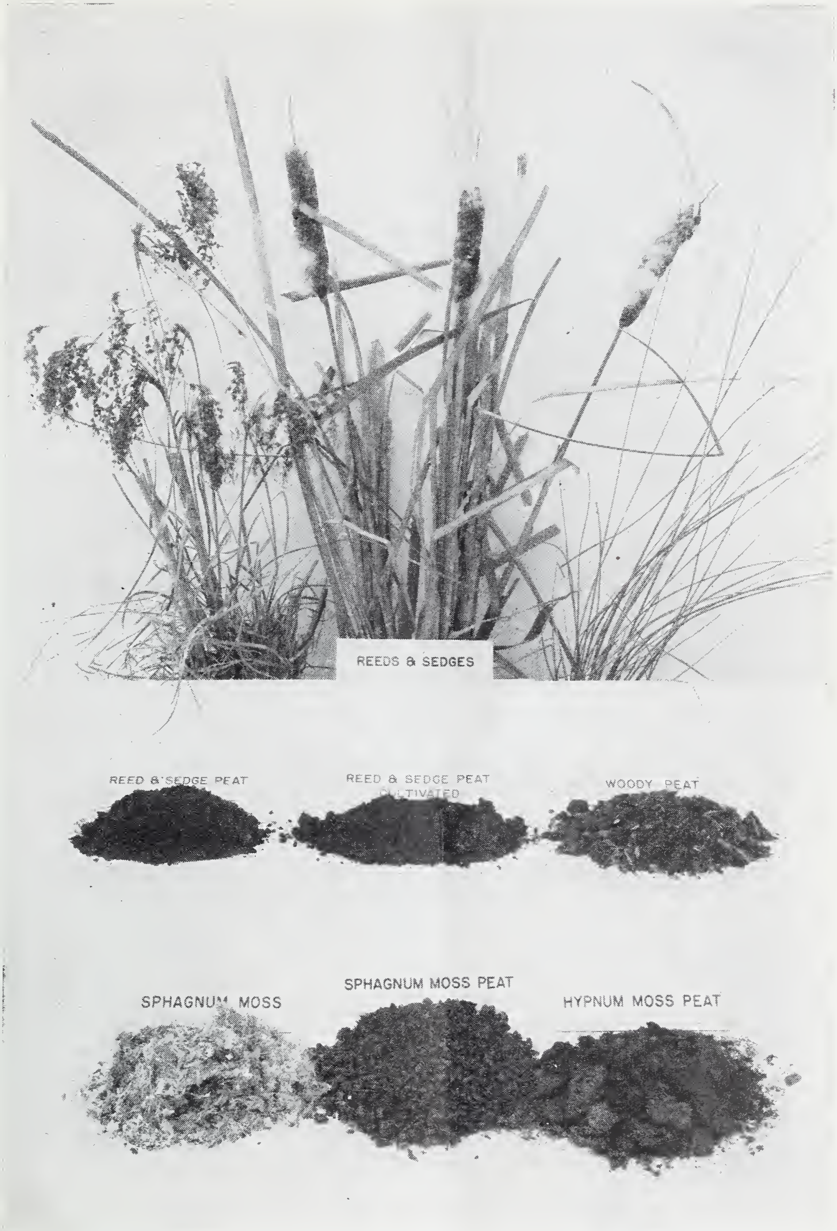


FIGURE 2.—Principal kinds of peat-forming plants, and peats derived from them.

clude leatherleaf, bog-rosemary, Labrador-tea, huckleberry, and blueberry. Other plants often present are alder, dwarf birch, sumac, chokeberry, buttonbush, willow, and cornel. Among the trees that normally succeed the shrubs are red maple and elm, and, in more northern areas, birch, larch, black spruce, and, usually in more calcareous regions, arborvitae. The greater part of such peat consists of material derived from roots, trunks, branches, twigs, and bark, in a tangled mass and not highly decomposed, mixed with remains of leaves, ferns, rootlets, and often in a matrix of more finely divided material.

The terms "highmoor" and "lowmoor" designate two general classes of peat. Highmoor refers to a marshy, treeless area of relatively low evaporation, with low-lime soils. The peat formed there is normally of strongly acid reaction. Lowmoor includes a plant association dominated by grasses, sedges, reeds, and rushes, normally growing in environments better supplied with calcium and potassium than are highmoor areas.

Sources of Peat in the United States

Peat and muck lands in the United States total about 79,000,000 acres. The major areas are: Northern Great Lakes States—Michigan, Wisconsin, and Minnesota; New England States, particularly Maine; the Dismal Swamp in eastern Virginia and North Carolina; the Okefenokee Swamp in southern Georgia and adjacent Florida; the Everglades of Florida; the Pacific Northwest; and the Delta area in central California. Other areas are found in New Jersey, Iowa, Illinois, Ohio, New York, and other States. The areas are shown in detail in a series of maps by Marbut (*35*). Organic soils are described in the 1938 Yearbook of Agriculture (*54*).

Peat bogs in almost any part of the United States may contain sphagnum. This does not mean, however, that such vegetation has had a dominant part in forming the peat. For example, scattered polsters of sphagnum on the surface do not necessarily indicate a deposit of sphagnum peat. As a rule, real sphagnum moss, or highmoor peat, is restricted to an area bounded roughly on the south by a line reaching from south-central Maine through north-central New York to north-central Minnesota and British Columbia. South of this approximate line, reed and sedge peats dominate. Peat that is composed mostly of reed and sedge remains is frequently of nearly neutral reaction. Instead of being typically lowmoor, however, reed-sedge peat may be very acid, with a low content of bases, and it is this type that is usually marketed. Highmoor, or sphagnum, peats predominate in northern Europe. Part of the commercial peat used in this country comes from northern Europe; about one-third of the total supply comes from Canada. Sphagnum and hypnum peat in limited quantities are marketed from Maine, Minnesota, and other Northern States.

Physical Character of Peat

The physical properties of peat that are of most interest to the user include water-holding capacity, weight of given volume, or specific gravity, and state of subdivision.

Water-holding power is of great importance in connection with certain agricultural uses (*22*). Sphagnum moss has tremendous water-holding power (*21*).

Moss peat has properties similar to those of a sponge. After once drying, the water-holding power is permanently diminished, but peat formed from this class of vegetation still has distinctive water-holding properties compared with peats derived from other types of vegetation.

Many peats are not readily wetted by water after becoming air-dry. Drying a naturally wet peat always diminishes the capacity of the material to take up water and hold it against gravity. But dried peat is still able to take up and hold much more water than is held in most mineral soils. This property gives peat its distinctive value for certain purposes.

Water-holding capacity is measured in different ways. The value most often used is the maximum amount held. It is determined by immersing peat in water for 2 hours, allowing to drain overnight in a bell jar, and then weighing. The difference between this weight and the oven-dry weight after 5 hours at 100° C. is the amount of moisture held. Another moisture value, one commonly used in soil science, is the so-called moisture equivalent. Saturated material is subjected to a force of 1,000 times gravity in a centrifuge for 40 minutes. The water retained is known as the moisture equivalent. Feustel and Byers (*20*) showed that the water-holding capacity of sphagnum peat is normally much higher than that for peat of other botanical origin (table 1). Air-drying greatly decreases the maximum water-holding powers of the various peats, but moisture-equivalent values are not greatly influenced by previous drying. This means that a great deal of the water in peat is loosely held.

TABLE 1.—*Moisture-holding capacities of peats as determined by different procedures*

Type of peat	Location	Depth	Maximum moisture-holding capacity		Moisture equivalent		Ash content, dry basis
			In natural wet condition	After air drying	In natural wet condition	After air drying	
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sphagnum....	Maine...	3–6	3,235	2,000	628	600	4.47
Do.......	....do....	24–36	2,640	1,620	562	504	....
Do.......	....do....	2–4	3,210	2,370	481	452	2.31
Do.......	....do....	12–18	1,475	366	492	274	1.88
Sawgrass......	Florida...	94–96	1,485	392	501	204	17.82
Do.......	....do....	10–16	1,360	370	488	216	7.73
White-cedar forest.	North Carolina.	36–42	643	162	346	101	27.05
Woody sedge..	Washington.	0–6	300	299	108	111	10.84

The weight of a given volume of peat in its natural condition varies widely with the character of the material. This is usually indicated by the apparent specific gravity, which is the weight of a given volume of the material as found compared with the weight of an equal volume of water. The absolute specific gravity is the weight of a unit volume of material without any air spaces or pores. Apparent specific gravities of peat given by Feustel and Byers (*20*) range from 0.413 to 1.158. This value is generally much higher for any peat when the material is wet than when it is dry. Feustel and Byers give the apparent specific gravity of a sample of saturated sphagnum peat as 1.01 and of the oven-dry material as 0.14. The absolute specific gravity is 1.59. The various kinds of peat usually do not differ greatly in apparent specific gravity of saturated material, or in absolute specific gravity. Apparent specific gravity of air-dry materials does, however, vary widely.

A cubic yard of peat in bulk as frequently sold ranges in weight from 700 to 1,200 pounds. The usual moisture content ranges from 30 to 70 percent. The organic-matter content of a cubic yard of such peat is likely to be about 450 pounds. Dried and shredded peat in bulk is materially lighter. A weight of about 8 pounds a bushel is frequently assigned to such material. Bales of commercial sphagnum peat, weighing about 175 pounds, are sometimes marked as containing 22 bushels (measured before compression). Such bales, as ordinarily marketed, have over-all dimensions of about 36 by 22 by 23 inches. But these measurements and the contents expressed in bushels are subject to considerable variation. Bales on the market vary in actual volume (as compressed) between 5 and 8 bushels.

The consumer's interests would be better served if the quantity of peat in a bale could be standardized, and the standardization put on the basis of weight rather than volume.

Chemical Composition of Peat

The chemical properties of peat may be considered from several standpoints. Practically all scientific studies of the amount of nutrient elements in peat have been reported on a dry basis. Most State laws, however, require that nutrient contents, if mentioned, must be guaranteed on the basis of material as sold.

Soil scientists are often concerned with the composition of ash from completely burned peat. The quantities of certain organic constituents present are also frequently reported. It is believed, however, that farmers and gardeners are likely to want to know particularly the amount of organic matter they are buying (dry basis) and the intensity of acidity of the material (pH). This involves determinations of moisture, ash, and pH. Occasionally there is interest in the plant nutrient content, particularly that of nitrogen (table 2). Generally, however, this is a minor factor in consideration of the material as it is used for direct application to soil.

Analyses of peats of different types (table 2) show that the reed-sedge group, which varies widely in botanical character, also varies widely in nitrogen content. The sawgrass peats are normally of higher nitrogen content than other reed-sedge deposits. The nitrogen of peat is only slowly available (*34*), and when peat

TABLE 2.—*Chemical composition of peats and muck on a dry basis*

Type of peat	Organic matter	Nitrogen (N)	Phosphoric oxide (P_2O_5)	Potash (K_2O)	Lime (CaO)	Acidity
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*pH*
Sphagnum moss......	95–99	0.7–1.2	0.02–0.10	0.02–0.05	0.03– 0.80	3.2–4.5
Reed and sedge.....	85–95	1.5–3.0	.05– .20	.03– .09	.70– 5.50	4.5–7.0
Woody......	75–90	.8–3.5	.06– .25	.05– .15	.30– 1.00	3.6–5.5
Sedimentary.	60–80	.7–4.0	.03– .20	.01– .30	.5–14.00	4.5–8.0
Muck.......	40+	.7–2.5	....	....	....	4.0–8.0

in small quantities is mixed with nitrogen-deficient soils the nitrogen is often insufficient for good plant growth. However, when a peat bog is drained and cultivated the nitrogen present in such a relatively large volume is usually adequate for good crop production, provided other nutrients are available in ample supply. In early spring, however, or during wet periods or when the soil is not well drained, applications of fertilizer nitrogen may be necessary to produce best results. In the very strongly acid and low-lime peats, such as highmoors, nitrogen is inadequate for maximum crop production, even though the peats are drained and limed.

The inorganic composition of the ash of peats (table 3), with the exception of the P_2O_5 content, is similar to that of certain calcareous soils. Plant tissues, when immersed in water, tend to lose

TABLE 3.—*Partial chemical composition of ash from various domestic peats* [1]

Type of peat and location	Depth	Ash, dry basis	Inorganic constituents							
			Silica (SiO_2)	Iron oxide (Fe_2O_3)	Alumina (Al_2O_3)	Phosphoric oxide (P_2O_5)	Lime (CaO)	Magnesia (MgO)	Potash (K_2O)	Manganese oxide (MnO)
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sphagnum. (Maine)	2–4	4.47	51.75	6.77	14.85	2.21	10.55	5.21	0.71	0.37
Sphagnum. (Maine)	2–4	2.31	29.49	3.34	12.23	2.83	22.81	9.36	3.29	.90
Heath..... (North Carolina)	0–3	7.17	65.28	4.24	10.63	1.80	8.10	4.50	.69	.06
Sawgrass (reed)... (Florida)	0–4	8.54	25.96	2.10	1.74	2.55	34.75	4.20	.80	.16
Woody sedge... (Washington)	0–6	10.84	34.28	28.20	11.40	3.95	11.90	2.33	.86	.80

[1] Data from Feustel and Byers (*20*).

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potash more readily than calcium, a chemical characteristic that is reflected in the composition of peat ash.

The contents of the organic constituents varies widely (table 4), probably because cellulose tends to decompose more rapidly under most conditions than does lignin.

TABLE 4.—*Principal constituents of the organic matter of various peats* [1]

Type of peat and location	Depth	Total organic matter	Sum of ether, alcohol, and water-soluble material	Hemicellulose	Cellulose	Lignin-humus complexes
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sphagnum (Orono, Maine).	2–4	95.53	15.79	25.2	13.3	17.89
Sphagnum (Cherryfield, Maine).	2–4	97.69	13.22	24.3	16.9	18.89
Heath (Beaufort, N. C.)	0–3	92.83	12.30	10.8	5.3	49.30
Sawgrass (reed) (Belle Glade, Fla.)	0–4	91.46	6.29	11.8	3.6	43.47
Woody sedge. (Monroe, Wash.)	0–6	89.16	18.14	8.1	2.7	35.64

[1] Data from Feustel and Byers (*20*).

Determinations were made also on a number of peats in current use (table 5).

TABLE 5.—*Important properties of several kinds of peat currently marketed or cultivated as soil* [1]

Kind of peat	Location	Acidity [2]	Water-holding capacity [3]	Ash content [3]
		pH	*Percent*	*Percent*
Sphagnum moss	Maine	3.7	798	0.9
	Poland	3.2	970	2.4
Hypnum moss	Iowa	5.7	736	15.2
Reed and sedge	Indiana	4.9	269	10.3
	Michigan	4.3	535	6.9
	Georgia	4.1	332	6.3
	Florida (northern area)	4.4	228	7.7
Cultivated commercial reed and sedge.	New Jersey	5.6	461	19.7
Cultivated muck soil	Ohio	5.0	263	16.3

[1] Unpublished data by R. S. Clark and B. J. Epstein.

[2] 1:4 peat-water ratio.

[3] Oven-dry basis.

Most of the peat used as fertilizer filler or sold as a fertilizer material is of the reed-sedge type. Chemical analyses of peat regularly reported by fertilizer-control officials are not ordinarily identified as to type. Nearly all are referred to merely as peat or humus. The nitrogen content of 907 samples called peat in such reports varied from 0.35 to 3.50, with a mean of 1.88, and that of 56 samples referred to as humus from 0.36 to 3.55, with a mean of 1.85. Other determinations were also similar for both peat and humus. So it may be assumed that the fertilizer trade makes no distinction between the terms "peat" and "humus."

All available determinations of fertilizer-grade peat were collected from the literature and combined as a composite analysis (table 6).

The vast majority of these peats contain between 1.0 and 2.2 percent nitrogen. When the nitrogen exceeds 2.0 percent the material has generally been artificially dried. A large number of minor elements are sometimes present in peat.

About half the nitrogen in peat is insoluble in fairly strong acids and is of little or no value as a plant nutrient. Although its exact chemical formula is not known, this nitrogenous compound is believed to be similar to horn, hair, and chitin. Lipman and Wank (*34*) found that neither steaming nor digestion in concentrated sulfuric acid made this nitrogen available.

From analyses of pine-forest humus and a review of the literature, Heyward and Barnette (*28*) found material of this type to have the following mean composition (in terms of percent on the dry basis): N, 0.53; P_2O_5, 0.15; K_2O, 0.12; CaO, 0.95; MgO, 0.17; and ash, 2.57. These values are low as compared with those for peats of other types. The organic-matter content, however, is very high.

Analysis of sedimentary peat made in this Bureau showed the following results: Organic matter, 24.32 percent; ash, 69.7; and moisture, 6.02. The organic matter contained 0.63 percent nitrogen. The ash contained 0.1 percent P_2O_5 and 1.2 percent CaO. Five determinations of nitrogen in sedimentary peat ranged from 0.63 to 3.15, with a mean of 1.84 percent.

Other analyses of typical peats and additional information on the chemical constitution and properties of peat are given in the literature (*9, 20, 36, 37, 58*).

USES OF PEAT

Peat is used for soil improvement, as a fertilizer conditioner, as bedding for horses and cattle, as poultry litter, for packing plants, cut flowers, and certain vegetables for shipment to market, as a fuel, and for other industrial and technical purposes (*24, 25, 29, 46, 57, 58*). Estimates of the quantities used for purposes of interest to agriculture in the United States are given in table 7.

Peat is widely used for fuel in foreign countries, where labor is cheap, especially in northern Europe, but very little is used for this purpose in the United States (*42, 50*). With our large domestic

TABLE 6.—*Composite chemical analysis of fertilizer-grade peat, on an air-dry basis*

TOTAL CONSTITUENTS

Constituent	Samples	Minimum	Maximum	Average
	Number	*Percent*	*Percent*	*Percent*
Lime (CaO)	207	0.15	5.94	1.58
Magnesia (MgO)	50	.06	2.48	.60
Potash (K_2O)	147	.01	.56	.16
Soda (Na_2O)	38	.06	.44	.14
Alumina (Al_2O_3)	29	.029	2.23	.59
Iron oxide (Fe_2O_3)	29	.06	3.38	.73
Silver oxide (AgO_2)	3	(1)	(2)	(3)
Gold oxide (AuO)	1			(4)
Barium oxide (BaO)	2	.06	.33	.19
Copper oxide (CuO)	3	.004	.100	.075
Germanium oxide (GeO_2)	2	(5)	(5)	(5)
Manganese oxide (MnO)	21	.014	.044	.025
Molybdenum oxide (MoO_3)	2	.001	.004	.003
Nickel oxide (NiO_2)	4	.001	.038	.009
Lead oxide (PbO)	2	.000	.003	.001
Strontium oxide (SrO)	2	.06	.36	.21
Titanium oxide (TiO_2)	29	.005	.300	.073
Zinc oxide (ZnO)	2	.000	.010	.005
Carbon dioxide (CO_2)	29	.00	4.03	1.03
Phosphoric oxide (P_2O_5)	157	.01	1.86	.25
Sulfur trioxide (SO_3)	99	.07	3.85	.64
Arsenic pentoxide (As_2O_5)	1			.005
Boric oxide (B_2O_3)	4	.0003	.080	.021
Chlorine (Cl)	5	.01	.32	.11
Chromium trioxide (Cr_2O_3)	2	.001	.011	.006
Silica (SiO_2)	97	.22	22.75	4.67
Vanadium trioxide (V_2O_3)	2	.000	.015	.007
Organic matter	177	12.47	94.67	68.88
Moisture	589	2.17	66.23	19.62
Total				99.630
O–equivalent of Cl				.025
Corrected total				99.605
MISCELLANEOUS DETERMINATIONS				
Inorganic nitrogen (N)	6	.001	.17	.04
Soluble organic N	5	.00	.05	.03
Water-soluble N	17	.03	.35	.08
Active insoluble N	14	.22	1.17	.57
Inactive insoluble N	15	.24	1.59	1.20
Acid-insoluble N	28	.10	1.61	.85
Total N	1.086	.35	3.55	1.86
Available P_2O_5	11	.11	.76	.34
Soluble SiO_2	27	.12	3.96	.91
Acid-insoluble SiO_2	29	.09	68.46	3.61
Crude protein	20	2.75	19.63	12.07
Cellulose	28	.40	11.78	4.01
Hemicellulose	28	.48	17.36	6.99
Lignin and humin	28	12.32	47.21	30.63
Ether extract	136	.15	6.55	1.30
Ash	223	.59	65.48	10.92
Moisture-holding capacity	34	107	2.370	646

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[1] 0.000,01. [2] 0.000,05. [3] 0.000,03. [4] 0.000,002. [5] 0.000,7.

TABLE 7.—*Production, importation, and estimated consumption of peat, selected years 1908 to 1950*

Year	Production[1]	Imports[2]	Estimated consumption[1]			
			Soil improvement	Fertilizer filler	Poultry litter and stable bedding	All other
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1908....	24,800	8,130	6,000	17,000	8,000	2,000
1913....	33,200	10,983	8,000	20,000	10,000	6,000
1918....	107,261	None	20,000	59,000	[3] 300	28,000
1923....	61,355	5,973	28,000	30,000	6,000	3,000
1928....	70,000	40,087	40,000	40,000	20,000	10,000
1933....	35,000	41,217	25,000	20,000	26,000	5,000
1938....	78,000	69,509	79,000	32,000	35,000	2,000
1939....	88,000	78,611	92,000	33,000	40,000	2,000
1940....	98,000	21,689	79,000	30,000	10,000	1,000
1941....	102,000	30,342	77,000	33,000	20,000	2,000
1942....	90,000	49,236	56,000	40,000	41,000	2,000
1943....	79,000	59,427	65,000	36,000	36,000	1,000
1944....	97,000	64,383	85,000	36,000	39,000	1,000
1945....	107,000	77,673	93,000	39,000	48,000	5,000
1946....	140,707	84,078	128,000	45,000	50,000	2,000
1947....	136,232	79,567	131,000	50,000	34,000	1,000
1948....	129,581	91,073	129,000	56,000	36,000	1,000
1949....	129,532	94,747	121,000	60,000	38,000	5,000
1950....	130,723	124,861	161,000	56,000	31,000	8,000

[1] United States Bureau of Mines, Minerals Yearbook, Corgan and Chiriaco (*6*), and other sources, except for 1928 and 1933, which were estimated by the authors.

[2] Data from U. S. Dept. of Commerce, 1908–45, (*51*); 1946–50, (*52*).

[3] Low tonnage result of war restrictions on importations, which fill most of the demand.

supplies of coal and oil, the use of low-grade fuel, such as peat, arouses little interest.

In the following discussion only agricultural uses are considered.

FOR SOIL IMPROVEMENT

The most important use for peat in this country is for soil improvement. Such improvement comes about in various ways.

Peat of any kind tends to improve the physical condition of heavy-textured soils, and to improve the moisture status of most soils (*47, 56*). Sphagnum peat is especially effective for holding water in a form available to growing plants.

Peat, alone or with animal manure or compost, is useful for potting plants (*31*). Where peat is inexpensive, it may be composted with animal manure to make an excellent product for soil improvement. Peat seems to be growing in favor for building lawns. Directions given in different parts of the United States often specify that, in establishing a new lawn, a cubic yard (about 2½ bales) of peat be spread over 1,500 to 2,000 square feet of ground, worked in to a depth of 4 to 6 inches with a rotary tiller or other implement, and covered with an inch of soil (fig. 3), after which the seed or sod and fertilizer are applied in accordance with

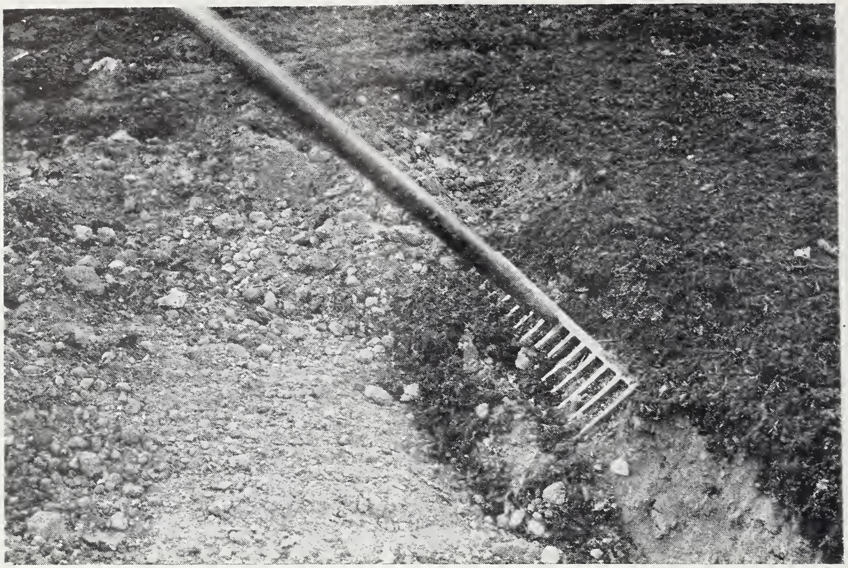

FIGURE 3.—Incorporating a surface application of 2 inches of peat with about 5 inches of soil to prepare a seedbed for a new lawn.

local practice. The neutral reed-sedge peats are widely used for this purpose. If acid peat is used, it may be necessary to add lime. Surface dressings of peat on established lawns are seldom effective (*38*).

Acid peat is an excellent medium in which to grow acid-loving plants such as azaleas (fig. 4) (*3, 23, 32*). It is also suitable as mulch for such plants. Many kinds of flowering plants grow better in soil to which peat has been added in moderate amounts.

Ornamental conifers and certain other perennial plants frequently grow best in a moderately acid soil. They may advantageously be mulched with acid peat (fig. 5).

Peat of any kind is a good medium for germinating seeds (*48*). It is used in tobacco seedbeds; about ¾ inch is spread over the bed and worked in to a depth of 4 inches before planting. Peat is also used in seedbeds for other plants that are to be transplanted. Seedlings in a frame filled with peat are much more easily transplanted then when sown in ordinary soil; the roots come free without breaking off, so that plants are not set back as much as when started in soil. The presence of a substantial quantity of peat in the soil appears to make any fertilizer more efficient. The high moisture-holding power of peat carries plants growing in it through droughts in better condition than would be the case in a mineral soil.

FOR FERTILIZER MANUFACTURE

The quantities of available plant nutrients in peat are too small to justify shipping it far as a fertilizer. Peat, merely as a source

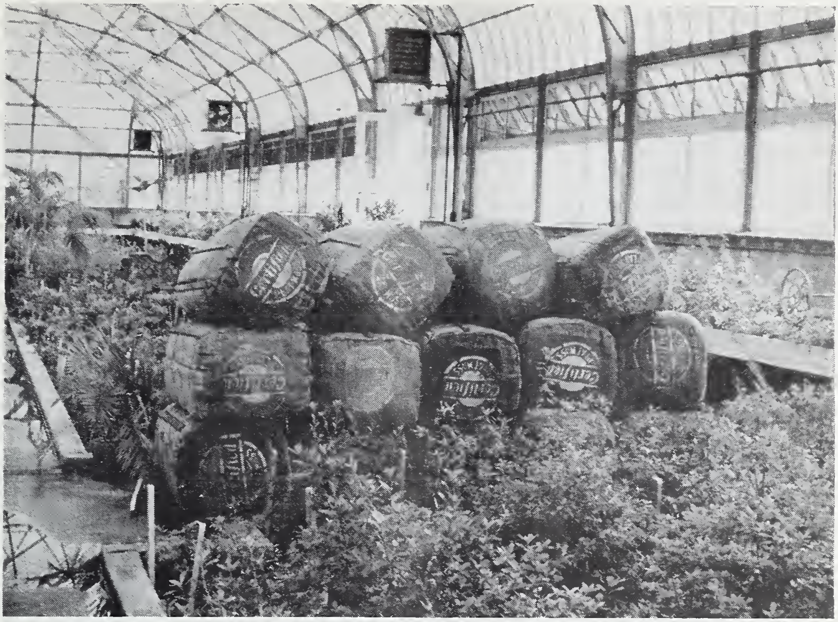

FIGURE 4.—Bundles of sphagnum moss peat in a greenhouse, where about 1 foot of soil was replaced by the peat for growing azaleas.

of plant nutrients, is not worth more than $5 a ton, and as a rule is worth much less than that.

Peat is used as a conditioner in the manufacture of mixed fertilizers (fig. 6) when it can be bought in a dried condition at a relatively low cost. Some fertilizer materials are hygroscopic, that is, they absorb moisture from the air in damp weather and dry out again in dry weather. As a result, they are sticky at times and harden into undrillable cakes at others, unless something is done to prevent it.

The use of peat does not keep hygroscopic salts from taking up moisture, but the ability of peat to absorb solution from the surface of the fertilizer particles may reduce stickiness or caking. Peat, like any other insoluble material, also reduces the number of contacts between particles of the active ingredients of the fertilizer mixture. The addition of 100 to 200 pounds of peat a ton may retard caking and improve drillability provided the initial moisture content of the mixture is low. Two hundred pounds of peat to a ton of mixed fertilizer is the maximum quantity usually recommended.

Reed-sedge peat is the kind used for fertilizer conditioner. It should be dried to a moisture content of 10 percent or less and screened through a 5- to 10-mesh sieve to be satisfactory. It is sold to fertilizer manufacturers in bulk only.

In making up fertilizer formulas it is customary, and usually desirable, to include some filler or cheap makeweight material to fill out the formula to an even ton. Sand or dolomite is often used

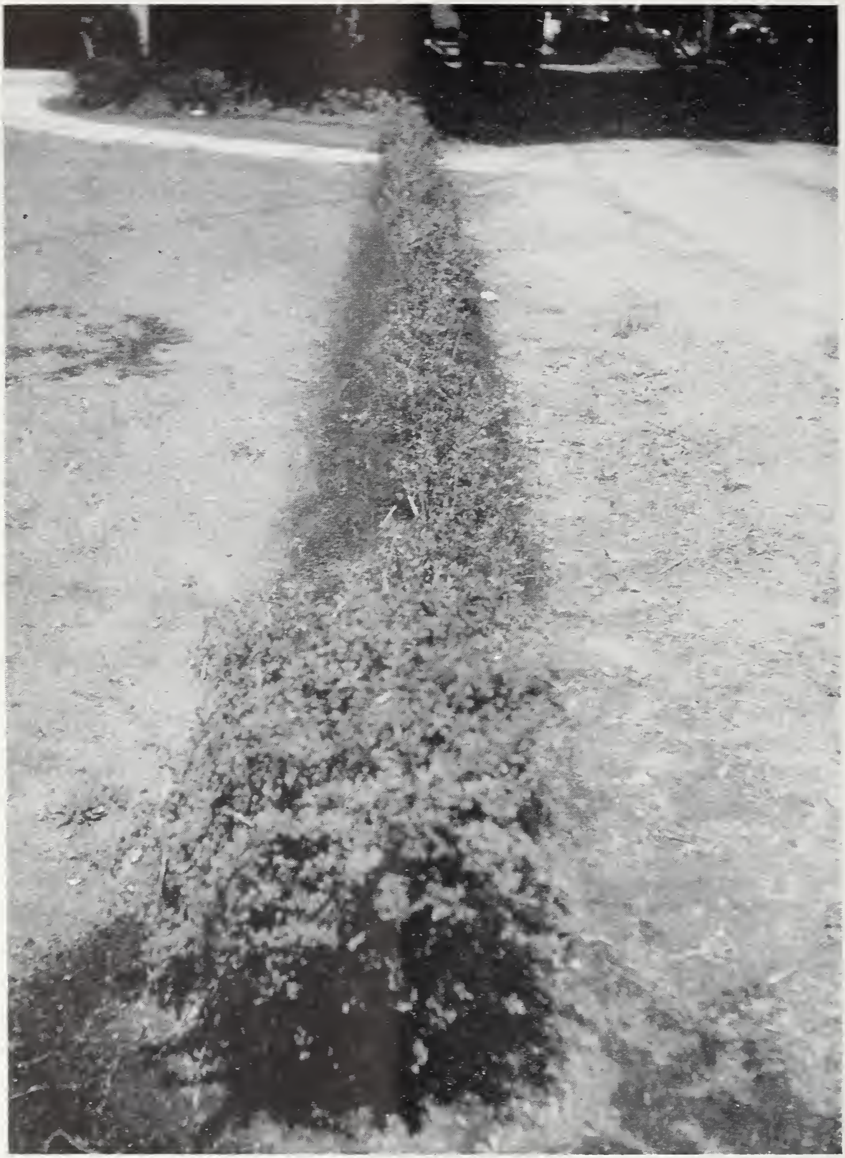

FIGURE 5.—Ornamental plants mulched with sphagnum moss peat.

for the purpose. Both conditioner and filler are unnecessary when one material, such as peat, can serve both purposes. Air-dry peat, when the cost is low enough, is preferable to sand.

Eight domestic companies, scattered from Maine to Florida and in Illinois, have produced most of the peat sold for use in manufacturing mixed fertilizers in the United States (table 7). A small part of the tonnage has been imported from Canada.

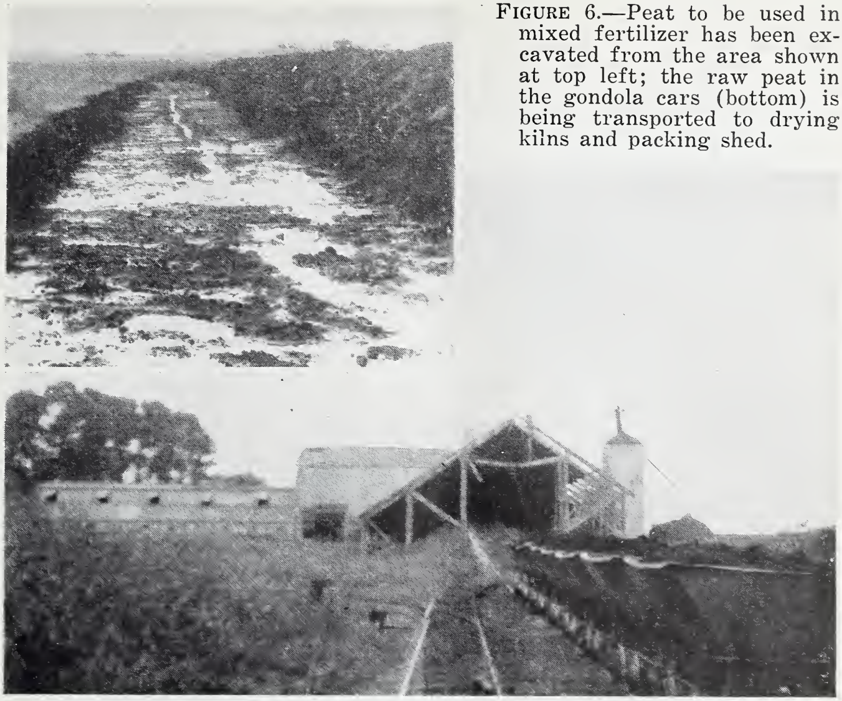

FIGURE 6.—Peat to be used in mixed fertilizer has been excavated from the area shown at top left; the raw peat in the gondola cars (bottom) is being transported to drying kilns and packing shed.

FOR BEDDING OR LITTER

From one-sixth to one-fourth of the peat used in the United States each year (table 7) is for litter in chicken houses or for animal bedding in barns. It may be assumed that most of the material used in this way later reaches the land in the form of manure mixtures. Such mixtures should be favorable for soil improvement; chicken manure, as well as any liquid manure absorbed from animal excretions, is relatively high in nitrogen and contains other essential plant nutrients. Such organic materials should be suitable for direct application to land without composting.

MISCELLANEOUS HORTICULTURAL USES

Peat is sometimes used as a packing medium for plants that must be kept damp for several days. Sphagnum moss that has undergone very little decomposition is commonly used for packing cut flowers for delivery. The more decomposed peats of different kinds are used to protect the roots of plants while being marketed. Moss peat is pressed into boards that are used to line asparagus crates. After the crate is filled the peat is moistened. The shoots are then kept in good condition long enough to reach market. This illustrates one of the many ways in which the high moisture-holding power of peat may be utilized to advantage in agriculture.

Harvesting and Preparing Peat for Market

Great variations exist in methods of mining, harvesting, and preparing peat for market. About 50 companies or individuals are producing peat for market in the United States (*4*). Usually, a preliminary step consists in draining at least the part of the bog selected for immediate use, controlling the drainage so that the water table can be raised or lowered within narrow limits.

It is generally necessary to lower the water table so that properly adapted mechanical equipment can be supported on the surface at certain seasons of the year (fig. 7). A soil surface should be provided over which light transportation equipment can operate, or a dragline should be rigged up from solid ground.

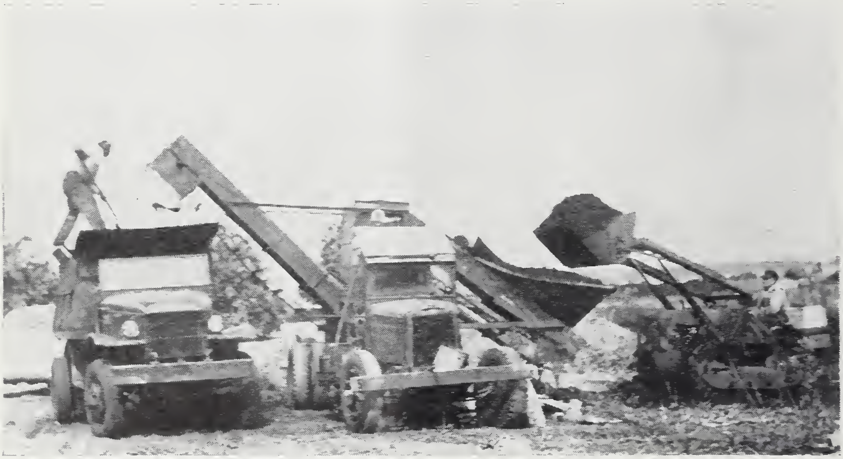

FIGURE 7.—The mechanical shovel delivers peat into a machine that shreds and screens it and then loads it into delivery trucks.

Drainage ditches deeper than 3 to 5 feet are likely to cause surface peat to dry so much that it becomes a fire hazard. In its incipient stages a peat fire is sometimes controlled by sheet-metal frames driven into the peat on all sides of the fire to act as barriers. There are other disadvantages to deep drainage (p. 27). The organic matter of well-drained peat bogs decomposes much more rapidly at the soil surface than in bogs where the surface is damp most of the time.

Mechanical equipment suited to the mining of sphagnum moss peat has not been developed. Much hand work is normally involved in the mining, or harvesting. A few years ago an implement in common use was a spade that had a second cutting blade at a right angle to the broader blade. More recently diggers have been using two separate implements—a broad cutting blade used for vertical insertion into the peat surface by which two dimensions of a block are laid out and a slightly curved, long narrow blade that is inserted horizontally for removal of a block (fig. 8). The blocks, often about 8 by 16 inches surface measurement and cut at a depth of about 8 inches, are sometimes placed in ricks, or stacks, to

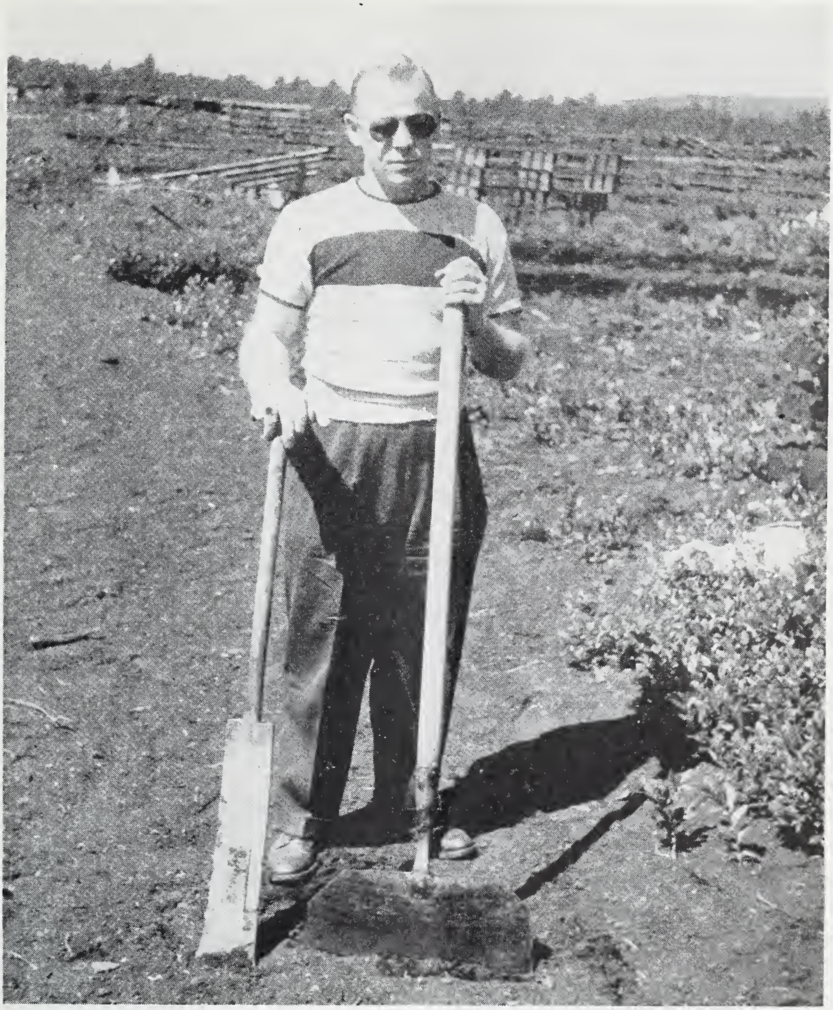

FIGURE 8.—Implements used for cutting and removing sphagnum moss peat from bogs.

drain and to dry. A more rapid method of drying involves stacking the blocks on wooden frames. When handled in this way the blocks may be air-dry in 2 or 3 weeks, while a whole season is often required for drying peat in ricks (fig. 9).

After drying, the blocks are taken to a storage house, where they are shredded, baled, and made ready for shipment. The shredding devices are usually modifications of grain-threshing equipment. Pegs, which take the place of the concaves in a thresher, are set against springs to take care of lumps too hard for shredding. Sometimes roots and other coarse particles are removed during the shredding process. Very coarse sieves, perhaps

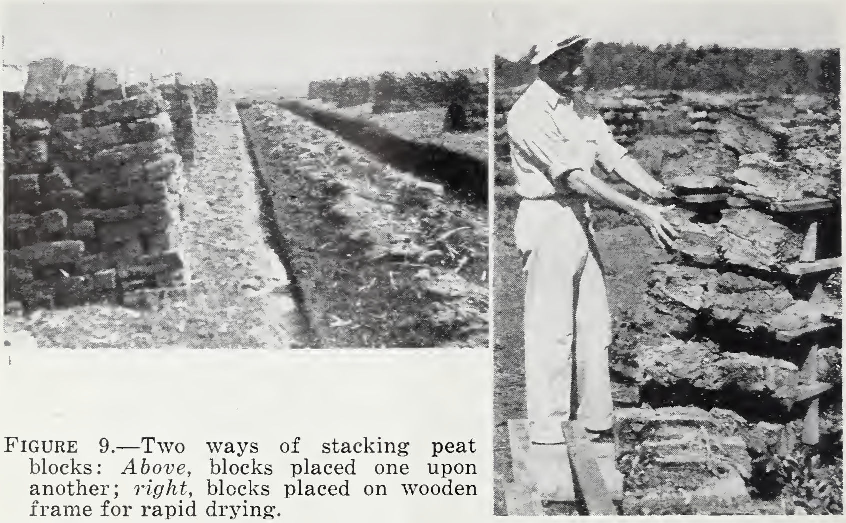

FIGURE 9.—Two ways of stacking peat blocks: *Above,* blocks placed one upon another; *right,* blocks placed on wooden frame for rapid drying.

of $3/8$-inch mesh, may be used to separate the large pieces or aggregates not suitable for marketing. Fineness is undesirable for certain types of peat prepared in a dry condition, but it may be desirable for the cultivated peats that are marketed without air drying.

Reed-sedge peat, as well as decomposed peat formed from certain mosses—particularly hypnum, is usually harvested by means of power equipment consisting of scrapers and loaders of various sorts.

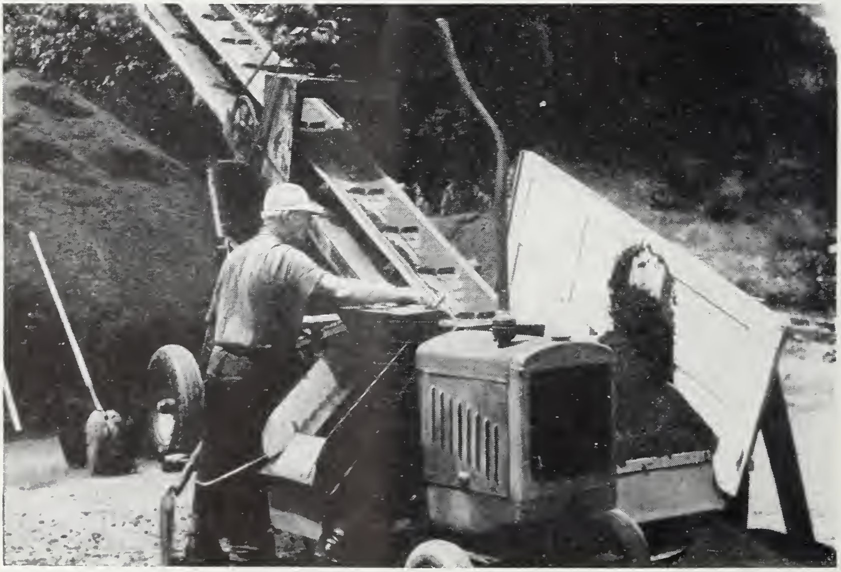

FIGURE 10.—Home-made equipment for screening and piling peat.

Some bogs are worked by home-made equipment, with the exception perhaps of a tractor and some kind of a scraper (fig. 10). Certain small-scale operators have found the draining of bogs unnecessary for removal of peat. For example, a single long pole, strongly guyed, supports a cable extending across the bog. On this cable a scraper or bucket is operated. The peat is drawn from the pond and dumped at the base of the upright, where water drains out of the pile, aided somewhat by pressure from the upper portion (fig. 11).

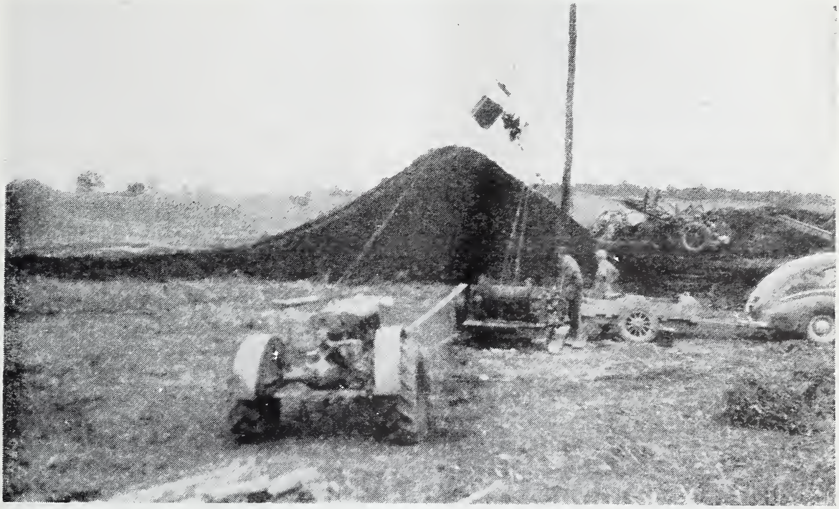

FIGURE 11.—Peat removed from a bog without previous draining in northern Indiana.

Distinctive features of harvesting so-called cultivated peat, or peat humus, include tilling at intervals for several months, or even several years, before shipment to market. A variety of field equipment may be used, including disk harrows and cultivators. This usually causes the peat to darken from brown to black. When a crop is grown and worked into the surface, changes similar to compost formation take place. Such peat may be expected to decompose more rapidly than raw peat when incorporated with soil. Figure 12 shows various steps in the development of cultivated peat from a reed-sedge deposit in New Jersey.

MARKETING PEAT

Peats as marketed vary in acidity, which is often important with respect to their use. The moisture content is usually relatively low in packaged or baled goods; frequently it is not specified. Bulk material is sometimes nearly saturated with water, in which case the peat is frequently sold by volume rather than by weight. In certain markets, peat plus poultry droppings is available on a fairly large scale. This mixture is sold in bulk as removed

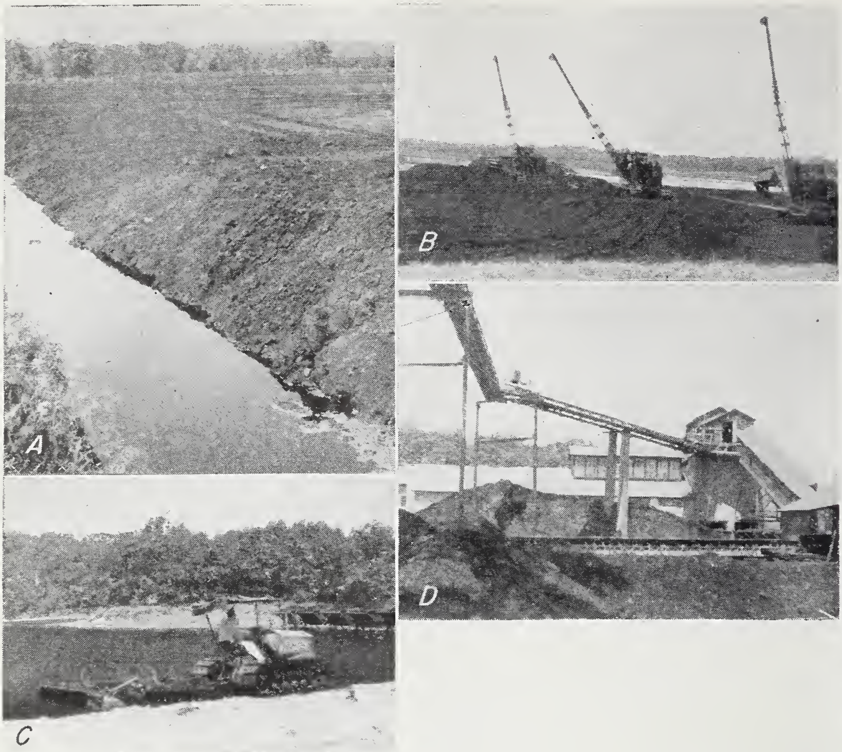

FIGURE 12.—Several stages of preparation and harvesting of cultivated peat in northern New Jersey: *A*, Drainage is made to a depth of approximately 3½ feet. The surface is then cultivated and one or more crops grown to give friability and black color; *B*, mechanical equipment is used to turn ricks of peat, thus improving its physical condition; *C*, calcareous material is discarded. The black peat is worked with disks, then piled and loaded onto small cars; and *D*, shredded peat is elevated for dumping into flat cars.

from poultry houses and in paper bags after drying, grinding, and screening.

Peat in bales or in cartons is relatively easy for the dealer and customer to handle, but the cost of preparation becomes a serious factor when the material is used as fertilizer filler, for preparation of large lawns, or in other ways requiring relatively large quantities. Retail garden-goods stores, landscape gardeners, and others frequently buy peat in bulk, shipped in open cars. This peat is sold in bags in the case of small purchases or in bulk when larger lots are wanted.

Because of the difficulty in maintaining water-holding properties when it is air-dried, peat is often sold for soil-improvement purposes in a moist condition. If cloth or burlap bags are used to hold it, they are seriously decomposed within a few weeks, and the purchaser should promptly remove the contents of the bag. Wooden boxes or slat crates held together with wire are more permanent but also more expensive.

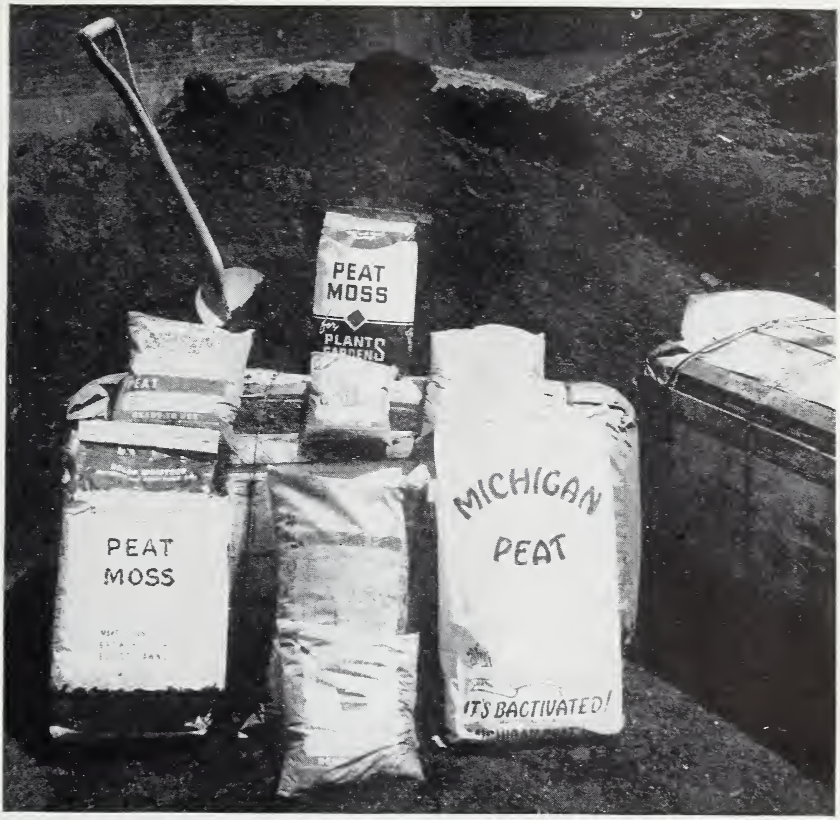

FIGURE 13.—Peat sold in local stores is sometimes in bulk, but more frequently that for the household or small garden is marketed in containers of various kinds and sizes.

At present peat is being extensively marketed in small plastic bags for use in potting plants (fig. 13). These bags do not decompose. They keep the peat damp until opened, but cost too much for large-scale use. Some brands consist of moist peat alone; others, of a potting-soil mixture. One sample was found to contain about 40 percent peat incorporated with sandy loam soil, plus a little 5–10–5 fertilizer mixed with compost or rotted animal manure and sand.

WHAT THE BUYER SHOULD KNOW

It is highly important that a dealer know whether he is selling peat that is acid or neutral in reaction. The range of acidity and alkalinity is expressed by the term "pH." Gardeners not familiar with the meaning of the pH scale should learn it. Neutral peat, neither acid nor alkaline, is said to have a pH value of 7. The more acid the material the lower the pH figure; the more alkaline the material the higher the pH. The pH values found in peats and mucks range from about 3.2 in certain sphagnum peats to about 8.5 in peats or mucks containing shells, marl, or limestone. Because the pH range may vary considerably even within a given class of peat, it is particularly important that the user know the acidity of the material he buys and the requirements of the plants he is growing. The seller should be able to supply this information.

The customer should also be informed about the necessity of keeping soils acid for certain perennial plants. The acid-loving plants include cranberries, blueberries, camellias, azaleas, rhododendrons, various junipers, red spruce, and most of the pines.

As commercial peats vary widely in moisture content and moderately in mineral matter, the merchant and the purchaser should know how many pounds of dry organic matter are being sold in a given weight of peat. An approximation of this value is easily calculated when the moisture and ash contents are known.

Specifications and Trade Practices

The Federal Trade Commission on January 13, 1950, promulgated Trade Practice Rules for the Peat Industry. One of the rules forbids representing a product as moss peat unless at least 75 percent, on a dry basis, is peat derived from mosses (*55*).

The State of New Jersey has specifications for peat that call for the kind of peat, the pH value, the moisture, the organic matter, and ash content of the peat as marketed (*59*).

The Bureau of Federal Supply has issued Federal Peat Specifications for use of all United States Government agencies in their purchases of the material (*53*).

In drawing up commercial specifications for buying peat it should be remembered that after the type of peat desired is decided upon, the content of organic matter is of greatest importance. For example, a material containing 30 percent organic matter, 3 percent ash, and 67 percent moisture would be worth only half as much as one of the same type containing 60 percent organic matter, 6½ percent ash, and 33½ percent moisture.

Needed Information

In the United States, foreign and domestic peats are often in competition. It is particularly important that the relative merits of different kinds of peat, both foreign and domestic, be known. Some of the features on which additional information is particularly needed are these:

1. Do peats of different botanical origin, but of like pH, produce the same effects on plant growth when added to soil or when used as a mulch?
2. When peat is added to a heavy-textured soil, is root penetration markedly improved?
3. Does the addition of sphagnum-moss peat to soil increase the supply of water available to plants more than the addition of peat of another kind?

4. How are volume weights of soils, rates of moisture loss by evaporation, and the total versus available moisture contents influenced by the addition of peat?
5. What factors should be considered in selecting peat as a constituent of potting soil or for other uses in greenhouse practice?
6. How do different kinds of peat compare with other organic or inorganic materials as conditioners for fertilizers?

PEAT AND MUCK LANDS FOR CROP PRODUCTION

Lands Under Cultivation

The area of peat and muck lands under cultivation in the United States is large, but exact acreage is not available. Such lands may be artificially drained to various degrees, or not drained at all, according to circumstances. The owner must decide whether his land is better fitted for cultivation or for development as a source of commercial peat or for neither. Peat or muck lands are often better adapted than mineral soils for the production of some special crops, as well as many truck crops. Such crops include potatoes, mints, lettuce, celery, onions, and cranberries.

In some places potatoes grown on such lands are reported to be of poor flavor, but a crop of good quality can usually be grown if native fertility is suitable or if the land is properly fertilized. Specialty crops such as mints and celery are grown on peat and muck soils, and cranberries are grown in eastern Massachusetts, New Jersey, and north-central Wisconsin. The choice of crops for organic lands depends on several factors, such as acidity, drainage, depth of peat, type of underlying mineral material, and climate (*27, 43, 57*).

The Everglades of Florida represent a very large area of peat and muck lands (*17, 22, 28*), with only a very small part developed for agricultural purposes. Most of this great swamp is underlain by limestone of coral origin, which provides conditions suitable for lime-loving plants unless the lime deposits are too far beneath the peat surface. Peat from this source is not suited for certain horticultural purposes that call for acid peats.

Varied crops are grown in different parts of the Everglades. South of Lake Okeechobee, sugarcane is successfully raised, and not far away are fields of sunflowers grown for seed, as well as winter-grown vegetables. In some places good forage is produced on properly drained lands. Para grass and Saint Augustine grass are among the grasses successfully grown. Applications of minor elements such as copper, manganese, and zinc are frequently necessary for satisfactory crops in this area.

The glaciated areas of the Northeast to Midwest have extensive muck lands. When adequately drained, the organic material usually supplies enough nitrogen for crops, with the possible exception of a small application of chemical nitrogen for starting spring growth. Fertilizer grades and rates of application used depend on the nutrient status of the soil and the requirements of each kind of plant. Minor elements are deficient in some areas.

Surveys in New York showed that muck-grown potatoes met higher grade standards than did upland-grown potatoes (*43*). Excellent potatoes are also grown on muck lands of northwestern Indiana.

Onions are an excellent organic-soil crop. Potential acreage of muck soil in onion-shipping counties of New York was estimated by Knott (*30*) at 400,000 acres, although in 1930 only about 30,000 acres were in actual production.

Various investigators have estimated the total muck-soil area in Michigan as at least 5,000,000 acres. Approximately 1 out of every 8 acres of the total land area of the State is muck. Large acreages have been developed for crop production (*27*). In that general area the term "muck" is frequently used to designate all kinds of highly organic soils. Wisconsin has from 3 to 4 million acres of muck lands, and Minnesota has 7 million, being proportionately less than in Michigan. In the northern parts of the three States such soils are left in their wild state or are used for hay or pasture.

In parts of the Corn Belt some so-called peat ponds are highly productive when drained. The deposit of peat in these areas generally varies from 8 inches to not more than 3 or 4 feet. Large yields of corn and other crops have been raised in rotation for several decades without use of commercial fertilizers. In some places peat may be removed to a depth of several feet and sold and the subsoil then drained for crop production, frequently yielding enormous crops of onions and potatoes (fig. 14).

Conservation of Organic Lands

Conservation of peat and muck lands requires careful attention to drainage, cultivation, and other phases of land management. Inadequate drainage leaves the land unsuited for the

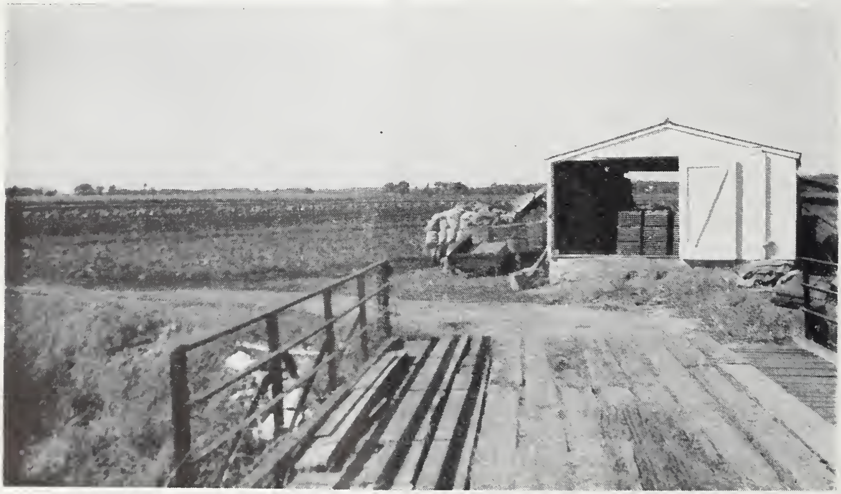

Figure 14.—Onions yielded 800 bushels per acre on this worked-over hypnum-moss area in 1949 in Iowa.

growth of most crops except certain grasses; on the other hand, lowering the water table beyond a certain point is undesirable. Control of the water table is needed not only to reduce the fire hazard, but also to prevent or minimize loss of organic matter by decomposition (*5*, *18*); to retain the original moisture status of the peat, which once lost is difficult to restore; to prevent wind erosion; and to provide the moist, easily wetted product demanded by some users of domestic peat.

Peat bogs that have been drained so some of the peat can be removed and sold usually have carefully controlled water tables. When not being worked, the water table is left at a level high enough to preclude danger of serious fire. The level of the water table of muck lands used for growing crops also is often controlled (fig. 15). In some places the highest yields have been obtained where the water table ranged from 24 to 42 inches below the surface. A water table at about 30 to 36 inches below the surface is considered best for small grains and cultivated crops. Higher water tables are best for meadows.

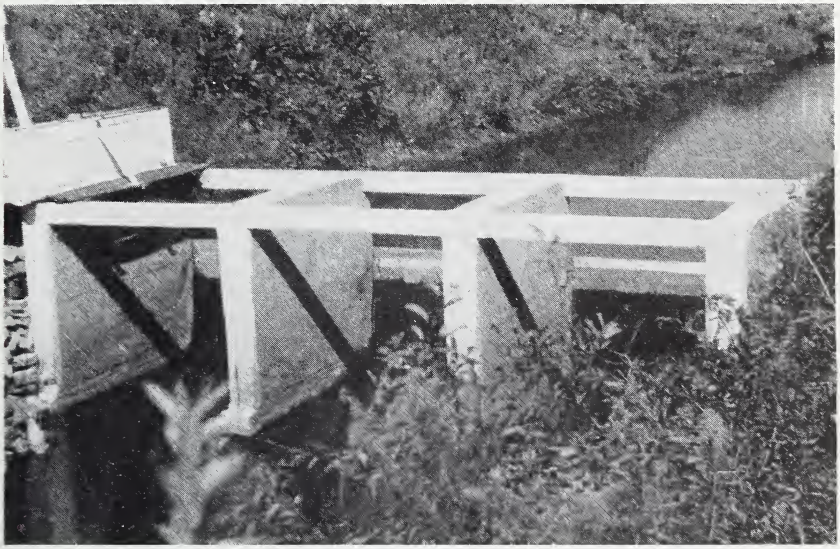

FIGURE 15.—A gate sometimes serves to raise or lower the water level several feet, depending upon whether subsurface irrigation or drainage is needed.

Neller, of the Florida Agricultural Experiment Station (*40*), found that the height of the water table had a marked influence on the rate of decomposition of organic matter in peat lands. Carbon dioxide evolution was taken as an index of rate of decomposition. A water table at 24 inches caused a tenfold increase in decomposition as compared with a 12-inch water table. When the water level was dropped to 36 inches, the rate of evolution of carbon dioxide was even greater. Such losses probably explain subsidence of the surface levels of organic lands not attributable to drying out or to compression by heavy machinery.

Precise determinations of subsidence of surface soil amounting to a few inches are not easy to make. Measurements of such changes have been made, however, on concrete walls and stakes driven to solid rock beneath the peat. Data from the Indiana Agricultural Experiment Station (*18*) indicate that the rate of subsidence amounts to about 0.1 foot a year over a water table at 36 to 40 inches. This is comparable with the rate of subsidence reported for a 20-year period in Florida (*40*).

The Muck Crops Experiment Farm of the Ohio Agricultural Experiment Station was recently established to study problems relating to organic lands of that State.

SUMMARY

This circular brings up to date a wide range of information concerning peat, and indicates different ways that it is useful in agriculture. Some new data are given regarding the chemical composition of commercial peats and methods of harvesting and preparing peat for market. The research worker will find information of a technical character, while lawn builders, gardeners, and producers and marketers of peat will also find specific practical suggestions. Large numbers of chemical determinations on peats have been gathered and summarized.

Domestic peats are usually formed primarily from plants of reed and sedge groups, but some moss peats are harvested and used. The imported peats are almost entirely of sphagnum moss origin.

Sphagnum moss peat is marketed in an air-dry condition, usually in the form of compressed bales. Reed-sedge peats are sometimes marketed air-dry, sometimes damp, and sometimes locally in a wet condition as taken from the bog.

Properties of peat that are of particular importance to the user include pH, moisture and ash contents, and state of subdivision. The dealer should be able to pass on to the customer some information regarding the properties indicated.

Further investigations are needed to determine the influence of botanical origin upon the suitability of peat for different uses.

LITERATURE CITED

(1) Alway, [F.] J., and Nygard, I. J.
1928. DIFFERENTIATION BETWEEN ACIDITY AND LIME-DEFICIENCY IN THE CASE OF PEAT SOILS. Internatl. Cong. (First) Soil Sci. Proc. and Papers 2 (1927): 22–44.

(2) Atwood, A. C., compiler.
1926. PEAT. A CONTRIBUTION TOWARDS A BIBLIOGRAPHY OF THE AMERICAN LITERATURE THROUGH 1925. U. S. Dept. Agr. Bibliog. Contrib. 12, 95 pp.

(3) Ballhorn, R. D., and Volz, E. C.
1948. THE INFLUENCE OF SOIL ACIDIFYING TECHNIQUES ON THE GROWTH OF AZALEAS. Amer. Soc. Hort. Sci. Proc. 51: 627–632.

(4) Chiriaco, G. V.
1950. DIRECTORY OF PEAT PRODUCERS IN THE UNITED STATES WHO REPORTED PRODUCTION OR SALES IN 1949. U. S. Bur. Mines, Mining and Market. Rpt. 1841, 4 pp. [Processed.]

(5) CLAYTON, B. S., NELLER, J. R., and ALLISON, R. V.
1942. WATER CONTROL IN THE PEAT AND MUCK SOILS OF THE FLORIDA EVERGLADES. Fla. Agr. Expt. Sta. Bul. 378, 74 pp., illus.

(6) CORGAN, J. A., and CHIRIACO, G. V.
1950. PEAT. U. S. Bur. Mines, Minerals Yearbook Preprint, 5 pp.

(7) DACHNOWSKI, A. P.
1919. QUALITY AND VALUE OF IMPORTANT TYPES OF PEAT MATERIAL. U. S. Dept. Agr. Dept. Bul. 802, 40 pp.

(8) ———
1922. PREPARATION OF PEAT COMPOSTS. U. S. Dept. Agr. Dept. Cir. 252, 12 pp.

(9) ———
1924. THE CHEMICAL EXAMINATION OF VARIOUS PEAT MATERIALS BY MEANS OF FOOD STUFF ANALYSES. Jour. Agr. Res. 29: 69-83.

(10) ———
1926. FACTORS AND PROBLEMS IN THE SELECTION OF PEAT LANDS FOR DIFFERENT USES. U. S. Dept. Agr. Dept. Bul. 1419, 23 pp., illus.

(11) DACHNOWSKI-STOKES, A. P.
1931. MOSS PEAT, ITS USES AND DISTRIBUTION IN THE UNITED STATES. U. S. Dept. Agr. Cir. 167, 12 pp., illus.

(12) ———
1933. PEAT DEPOSITS IN USA: THEIR CHARACTERISTIC PROFILES AND CLASSIFICATION. [AMERICAN PEAT DEPOSITS.] *In* Bulow, K. von, Handbuck der Moorkunde v. 7: 1–140, illus. Berlin.

(13) ———
1933. GRADES OF PEAT AND MUCK FOR SOIL IMPROVEMENT. U. S. Dept. Agr. Cir. 290, 30 pp., illus.

(14) ———
1936. PEAT LAND IN THE PACIFIC COAST STATES IN RELATION TO LAND AND WATER RESOURCES. U. S. Dept. Agr. Misc. Pub. 248, 68 pp., illus.

(15) ———
1941. PEAT RESOURCES IN ALASKA. U. S. Dept. Agr. Tech. Bul. 769, 84 pp., illus.

(16) DAVIS, C. A.
1916. PEAT. *In* Mineral Resources of the United States. U. S. Geol. Survey U. S. 1914 (Pt. 2): 375–385.

(17) DAVIS, J. H.
1946. THE PEAT DEPOSITS OF FLORIDA, THEIR OCCURRENCE, DEVELOPMENT, AND USES. Fla. Geol. Survey Bul. 30, 247 pp., illus.

(18) ELLIS, N. K., and MORRIS, R.
1946. PRELIMINARY OBSERVATIONS ON THE RELATION OF YIELD OF CROPS GROWN ON ORGANIC SOIL WITH CONTROLLED WATER TABLE AND THE AREA OF AERATION IN THE SOIL AND SUBSIDENCE OF THE SOIL. Soil Sci. Soc. Amer. Proc. (1945) 10: 282–283, illus.

(19) FEUSTEL, I. C.
[1940.] THE PRESENT STATUS OF RESEARCH RELATING TO THE USE OF PEAT AND MUCK AS SOIL AMENDMENTS. Soil Sci. Soc. Amer. Proc. (1939) 4: 271–274.

(20) ——— and BYERS, H. G.
1930. THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF CERTAIN AMERICAN PEAT PROFILES. U. S. Dept. Agr. Tech. Bul. 214, 27 pp., illus.

(21) ——— and BYERS, H G.
1936. THE COMPARATIVE MOISTURE-ABSORBING AND MOISTURE-RETAINING CAPACITIES OF PEAT AND SOIL MIXTURES. U. S. Dept. Agr. Tech. Bul. 532, 25 pp., illus.

(22) FLORIDA AGRICULTURAL EXPERIMENT STATION.
1948. SOILS, GEOLOGY, AND WATER CONTROL IN THE EVERGLADES REGION. Fla. Agr. Expt. Sta. Bul. 442, 168 pp., illus.

(23) FORET, J., and VOLZ, E. C.
1948. THE EFFECTS OF CERTAIN FERTILIZERS AND POTTING MEDIA ON GROWTH AND FLOWERING OF AZALEAS. Amer. Soc. Hort. Sci. Proc. 51: 633–638.

(24) Girard, H.
1947. PEAT IN QUEBEC, ITS ORIGIN, DISTRIBUTION, AND UTILIZATION. Canada Dept. Mines, Geol. Rpt. 31, 48 pp., illus.

(25) Haanel, B. F.
1925. PEAT, ITS MANUFACTURE AND USES, FINAL REPORT OF THE PEAT COMMITTEE. Canada Dept. of Mines, Mines Branch Bul. 641, 298 pp., illus.

(26) Hammar, H. E.
1929. THE CHEMICAL COMPOSITION OF FLORIDA EVERGLADES PEAT SOILS, WITH SPECIAL REFERENCE TO THEIR INORGANIC CONSTITUENTS. Soil Sci. 28: 1–13, illus.

(27) Harmer, P. M.
1941. THE MUCK SOILS OF MICHIGAN, THEIR MANAGEMENT AND USES. Mich. Agr. Expt. Sta. Spec. Bul. 314, 128 pp., illus.

(28) Heyward, F., and Barnette, R. M.
1936. FIELD CHARACTERISTICS AND PARTIAL CHEMICAL ANALYSIS OF THE HUMUS LAYER OF LONGLEAF PINE FOREST SOILS. Fla. Agr. Expt. Sta. Bul. 302, 27 pp., illus.

(29) Hotson, J. W.
1919. SPHAGNUM FROM BOG TO BANDAGES. Wash. [State] Univ. Puget Sound Biol. Sta. Pub. 2: 211–247, illus.

(30) Knott, J. E.
1930. GROWING ONIONS ON THE MUCK SOILS OF NEW YORK. N. Y. (Cornell) Agr. Expt. Sta. Bul. 510, 34 pp., illus.

(31) Laurie, A.
1930. THE USE OF PEAT IN THE GREENHOUSE. Mich. Agr. Expt. Sta. Spec. Bul. 194, 28 pp., illus.

(32) ——— and Kiplinger, D. C.
1945. CULTURE AND FORCING OF GREENHOUSE AZALEAS. Ohio Agr. Expt. Sta. Bimo. Bul. 30: 177–187, illus.

(33) Leverin, H. A.
1946. PEAT MOSS DEPOSITS IN CANADA. Canada Dept. Mines and Resources, Mines and Geol. Branch Bul. 817, 102 pp., illus.

(34) Lipman, C. B., and Wank, M. E.
1924. THE AVAILABILITY OF NITROGEN IN PEAT. Soil Sci. 18: 311–316, illus.

(35) Marbut, C. F.
1935. ATLAS OF AMERICAN AGRICULTURE, PT. III. SOILS OF THE UNITED STATES. U. S. Dept. Agr. Bur. Chem. and Soils, 98 pp., illus.

(36) Miller, C. F.
1918. INORGANIC COMPOSITION OF A PEAT AND OF THE PLANT FROM WHICH IT WAS FORMED. Jour. Agr. Res. 13: 605–609.

(37) Minssen, H.
1913. BEITRAGE ZUR KENNTNIS TYPISCHER TORFARTEN. Landw. Jahrb. 44: [269]–330.

(38) Monteith, J., Jr., and Welton, K.
1933. USE OF PEAT AND OTHER ORGANIC MATERIALS ON GOLF COURSES. U. S. Golf Assoc., Green Sect. Bul. 13: 90–110, illus.

(39) Morgan, M. F.
1940. PEAT AND SWAMP MUCK FOR SOIL IMPROVEMENT IN CONNECTICUT. Conn. Agr. Expt. Sta. Cir. 142, pp.[85]–96.

(40) Neller, J. R.
1944. OXIDATION LOSS OF LOWMOOR PEAT IN FIELDS WITH DIFFERENT WATER TABLES. Soil Sci. 58: 195–204, illus.

(41) Nichols, G. E.
1919. RAISED BOGS IN EASTERN MAINE. Geog. Rev. 7: 159–167, illus.

(42) Odell, W. W., and Hood, O. P.
1926. POSSIBILITIES FOR COMMERCIAL UTILIZATION OF PEAT. U. S. Dept. Com., Bur. Mines Bul. 253, 160 pp., illus.

(43) Pullen, W. E.
1947. MUCK AND UPLAND POTATOES. N. Y. (Cornell) Agr. Expt. Sta. Bul. 837, 40 pp., illus.

(44) Rigg, G. B.
1940. THE DEVELOPMENT OF SPHAGNUM BOGS IN NORTH AMERICA. I. Bot. Rev. 6: 666–693.

(45) Rigg, G. B.
1951. THE DEVELOPMENT OF SPHAGNUM BOGS IN NORTH AMERICA. II. Bot. Rev. 17: 109–131.
(46) Soper, E. K., and Osbon, C. C.
1922. THE OCCURRENCE AND USES OF PEAT IN THE UNITED STATES. U. S. Geol. Survey Bul. 728, 207 pp., illus.
(47) Sprague, H. B., and Marrero, J. F.
1932. FURTHER STUDIES ON THE VALUE OF VARIOUS TYPES OF ORGANIC MATTER FOR IMPROVING THE PHYSICAL CONDITION OF SOILS FOR PLANT GROWTH. Soil Sci. 34: 197–208.
(48) Stoutemyer, V. T.
1944. SPHAGNUM MOSS FOR SEED GERMINATION. U. S. Dept. Agr. Leaflet 243, 6 pp., illus.
(49) Swinnerton, A. A.
1945. PEAT IN CANADA. Canad. Geog. Jour. 31 (1): 18–[29], illus.
(50) Trefethen, J. M., and Bradford, R. B.
1944. DOMESTIC FUEL POSSIBILITIES OF MAINE PEAT. Maine Technol. Expt. Sta. Paper 46 (Maine Geol. Survey Bul. 1), 47 pp., illus.
(51) United States Bureau of the Census.
1848. FOREIGN COMMERCE AND NAVIGATION OF THE UNITED STATES FOR THE CALENDAR YEAR 1945. U. S. Dept. Com., 678 pp.
(52) ———
1950. MONTHLY SUMMARY OF FOREIGN COMMERCE OF THE UNITED STATES. U. S. Dept. Com., [491] pp.
(53) United States Bureau of Federal Supply, Treasury Department.
1947. FEDERAL SPECIFICATIONS FOR PEAT; MOSS, REED, AND SEDGE. Fed. Standard Stock Cat. Sec. IV, pt. 5: Q–P–166, 5 pp. [Processed.]
(54) United States Department of Agriculture.
1938. SOILS AND MEN. U. S. Dept. Agr. Yearbook 1938, 1232 pp., illus.
(55) United States Federal Trade Commission.
1950. TRADE PRACTICE RULES FOR THE PEAT INDUSTRY. 9 pp. [Processed.]
(56) Waksman, S. A.
1938. HUMUS. Ed. 2, 526 pp., illus. Baltimore.
(57) ———
1940. PEAT AND ITS USES. N. J. Agr. Expt. Sta. Bul. 681, 11 pp., illus.
(58) ———
1942. THE PEATS OF NEW JERSEY AND THEIR UTILIZATION. PART A. N. J. Dept. Conserv. and Devlpmt., Geol. Ser., Bul. 55, 155 pp., illus.
(59) ——— Bear, F. E., Cox, H. R., and Sprague, H. B.
1941. SPECIFICATIONS FOR PEAT MATERIALS. N. J. Agr. Expt. Sta. Cir. 407, 4 pp.
(60) Wilson, B. D., Eames, A. J., and Staker, E. V.
1936. GENESIS AND COMPOSITION OF PEAT DEPOSITS. N. Y. (Cornell) Agr. Expt. Sta. Mem. 188, 13 pp., illus.
(61) ——— and Richards, S. J.
1938. CAPILLARY CONDUCTIVITY OF PEAT SOILS AT DIFFERENT CAPILLARY TENSIONS. Amer. Soc. Agron. Jour. 30: 583–588, illus.
(62) ——— and Staker, E. V.
1932. THE CHEMICAL COMPOSITION OF THE MUCK SOILS OF NEW YORK. N. Y. (Cornell) Agr. Expt. Sta. Bul. 537, 26 pp., illus.
(63) ——— and Staker, E. V.
1933. THE CHARACTER OF THE PEAT DEPOSITS OF NEW YORK. N. Y. (Cornell) Agr. Expt. Sta. Mem. 149, 20 pp., illus.
(64) Wilson, J. K., and Wilson, B. D.
1933. THE OCCURRENCE OF AZOTOBACTER IN PEAT SOILS OF NEW YORK. N. Y. (Cornell) Agr. Expt. Sta. Mem. 148, 15 pp., illus.

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